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BIOLOGICAL EVAULATION OF A ROUNDHEADED PINE BEETLE OUTBREAK IN THE PINALENO MOUNTAINS, SAFFORD RANGER DISTRICT, CORONADO NATIONAL FOREST

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By

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ABSTRACT

An outbreak of the roundheaded pine beetle, Dendroctonus adjunctus was evaluated in the Pinaleno mountains of Southeastern Arizona. Mortality has occurred since 1988, becoming epidemic in 1991. A survey was conducted in the Riggs Flat Lake area to determine current conditions and predict future trends. Both ponderosa pine, Pinus ponderosa, and southwestern white pine, Pinus strobiformis have been attacked. The outbreak has reduced the ponderosa pine component substantially, favoring nonhost species. Over 50 percent of ponderosa pines are either dead or currently infested in 2 of 3 areas surveyed. Ratios 1992 to 1991 attacks indicate that the outbreak may continue to increase. Several management alternatives are discussed.

INTRODUCTION

Ponderosa pine mortality has been slowly increasing since 1988 in the Pinaleno Mountains, Safford Ranger District, Coronado National Forest. The Pinaleno Mountains are located in the Southeastern corner of Arizona. The primary bark beetle species associated with this mortality is the roundheaded pine beetle (RPB), Dendroctonus adjunctus. Technical information on this insect and commonly associated species may be found at the end of this document.

Aerial detection survey records indicate that mortality began in 1988. A summary of the outbreak history are shown in Figures 1-5. From 1988-1990 the mortality was limited to a few small pockets of trees, generally between 1 and 10 trees in size. In 1991, the number of trees and affected area increased several fold. In 1992, the number of affected acres increased slightly, but the number of dead trees increased dramatically. Large numbers of dead (fading) trees were detected in the vicinity of Riggs Flat, Merrill Peak, and Treasure Park. Prior to this outbreak, the last major bark beetle activity occurred in the Pinaleno Mountains during the 1970s.

A ground survey was conducted in December, 1992 in the Riggs Flat Lake area to determine population trends and stand conditions. The purpose of this report is to: (1) Describe current conditions, (2) project future trends and effects, (3) describe management alternatives, and (4) provide technical information on the insects involved.

METHODS

Based on the 1992 aerial survey results the Riggs Flat area was divided into three zones, Figure 6. In each area a systematic variable plot/fixed plot cruise was used to estimate bark beetle activity and current stand conditions. Two transect lines, 8 chains apart were placed along the longest axis of each area. Points were established at 5 chain intervals along each line. At each point a variable plot (35 basal area factor) and fixed plot (1/100 acre) were established. For all sample trees, species, diameter, tree condition (healthy, infested, or dead), and cause were recorded. From this information trees per acre (TPA) and square feet of basal area per acre (BA) were calculated by species, diameter class (dbh), tree condition and causal agent by zone.

RESULTS

Zone 1

Results for Zone 1 are summarized in Tables 1-4. Prior to this outbreak, the overstory in Zone 1 consisted primarily of southwestern white pine, Douglas-fir, and ponderosa pine with lesser amounts of aspen and white fir (Table 2). The understory was composed largely of Douglas-fir with some southwestern white pine, aspen, white fir, ponderosa pine, and Gambel Oak (Figure 2). Stocking levels were very dense with 301.9 trees per acre (TPA) and 248.2 square feet of basal area per acre (BA) in the overstory. Regeneration was abundant with over 1,000 seedlings and saplings per acre.

Since the outbreak, the number of TPA and BA has been reduced somewhat (Table 2). However, since this area contains a majority of Douglas-fir and southwestern white pine and primarily ponderosa pine has been affected, the outbreak has not had a tremendous effect overall. Less than 10 percent of the trees are infested or dead. The outbreak will increase the proportion of nonhost species such as Douglas-fir, white fir, aspen, and maybe southwestern white pine as well.

While from a whole stand basis the effects of the outbreak seem small, when only ponderosa pine is considered the situation is quite different (Tables 3 and 4). Over one third of the ponderosa pine trees are either infested or have been killed due to bark beetles. The trees that are currently infested are for all practical purposes dead now, however, their foliage will not fade or discolor until next year. While the number and basal area of live ponderosa pines has changed substantially, the average diameter has changed little. It was 11.3 inches prior to the outbreak and is now 11.8. Buildup ratios, ratios of currently infested to last years dead are used by some entomologists to provide an indication of outbreak trend. For this zone the ratio is 0.6:1 indicating that outbreak may be declining at this time.

Levels of dwarf mistletoe were very low or insignificant in this area, only 2.6 percent of the trees are infected. The stand dwarf mistletoe rating (DMR) rounded to 0.

Zone 2

Results for Zone 2 are summarized in Tables 5-8. Prior to this outbreak, southwestern white pine comprised approximately half of the overstory with lesser amounts of ponderosa pine, aspen, white fir, and Douglas-fir (Table 5). The understory was dominated by southwestern white pine as well, but there were also significant amounts of the other four species (Table 5). Stocking levels were very dense with 286.6 TPA and 204.2 BA in the overstory (Table 5).

Since the outbreak stocking levels have dropped some. Almost 10 percent of the overstory trees are infested or dead (Table 6). As with Zone 1, the outbreak has not had a tremendous impact yet on the area because of the large number of white pines, as well as Douglas-fir. The proportion of these species will increase in the future.

The ponderosa pine component of the stand has been reduced substantially (Tables 7 and 8), 56.8 percent of the trees and 46.5 percent of the basal area has been infested or killed by bark beetles. The average diameter has increased slightly from 10.7 inches to 12.2 inches. The ratio of infested to dead trees is 1.3:1 indicating that the outbreak is still building. However, since over 50 percent of the trees have now become infested or have been killed, the outbreak should begin to decline in this zone within the next year or two.

Dwarf mistletoe was present at very low levels in this area. A little over 3 percent of the ponderosa pines are infected. The average stand DMR was 0.1.

Zone 3

Results for Zone 3 are summarized in Tables 9-14. Zone 3 had a very different species composition from the other two stands. A majority of the TPA, and almost half of the BA in the overstory were ponderosa pine (Table 9). The understory was dominated by southwestern white pine (Table 9). Stocking levels were dense with 333.3 TPA and 210.0 BA in the overstory (Table 9).

About one third of the overstory trees in the stand are either currently infested or dead (Table 10). The species composition of this area will be changing substantially, favoring Douglas-fir, white fir, and aspen. Unlike the other two areas, some white pines were attacked in this area.

Over half of the ponderosa pines have been attacked by bark beetles in this area (Table 11). Almost 60 percent of the basal area is either currently infested or dead (Table 12). The average diameter of live pines increased slightly from 10.6 inches before the outbreak to 11.5 inches now. The ratio of currently infested to dead trees is 4.5:1 indicating an increasing trend, however since over half of the ponderosa pines are either dead or infested the outbreak will begin to decline in this species in this area next year.

Prior to this year white pines were not attacked during this outbreak, however almost 16 percent of the trees and 25 percent of the basal area are currently infested in this area (Tables 13 and 14). White pines are listed as host species for the roundheaded pine beetle, however, they are not mentioned as a primary host species in the United States. In past outbreaks in the Sacramento mountains of New Mexico, white pines were not affected very much. However, in Mexico, many pines, including mexican white pine, are listed as hosts. Because of this it is difficult to predict what will happen in the Pinalenos. It is possible that the beetles are attacking the white pines because so many of the ponderosa pines are already dead. This is not uncommon during bark beetle outbreaks. If this is the case, they may not reproduce successfully. However, since white pines are important hosts in Mexico it would be worthwhile to monitor the situation in the Pinalenos.

Dwarf mistletoe levels are low in this area, 15.8 percent of the trees are infected. The stand dwarf mistletoe rating was 0.2.

Overall

The primary bark beetle associated with this mortality appears to be the RPB. Ips species were found in very small diameter trees. The western pine beetle, Dendroctonus brevicomis, was not found during this survey but may be present as it is often associated with the RPB.

Survey results suggest an overall increasing trend in the Riggs Flat area. Two of the three areas surveyed displayed increasing trends. However, it is difficult to predict the exact course of bark beetle outbreaks, because other factors such as climate can drastically affect beetle populations. If this outbreak does continue to increase, it will most likely extend into adjacent or

nearby susceptible ponderosa pine stands. Susceptible stands are those with a large percentage of ponderosa pine, and dense stand conditions. The outbreak should begin to decline in the immediate area around Riggs Flat Lake within the next year or so, however, there will be a large number of fading trees visible next year that were attacked this fall.

The main effects of this outbreak will include: A reduction of the ponderosa pine component, canopy closure, and density; creation of openings or canopy gaps; an increase in snags and down woody material; a short term decrease in visual quality; a short term increase in fine fuels and later an increase in large fuels on the ground. The outbreak may not result in much change in the diameter distribution of ponderosa pine. The beetles are attacking all diameter classes 3 inches and greater. Presence of dead trees will create a hazard in the campground where located adjacent to camp pads, restrooms, parking areas, etc.

MANAGEMENT ALTERNATIVES

The determination of appropriate environmentally acceptable, economically sound pine beetle management strategies requires a good understanding of desired future conditions and resource management objectives from a site specific and a landscape perspective. Alternative strategies for managing bark beetle outbreaks are summarized below. Desired future conditions and resource management objectives for the area should dictate which alternative or mix of alternatives would be appropriate for each management area.

1. **Do Nothing**. Allow outbreak to subside naturally.

   Where Applicable. This alternative may be desirable in areas where control measures cannot be undertaken, where the outbreak is expected to decline anyway, or where mortality contributes to or does not conflict with the development of desired future conditions.

   Effects. Outbreak would continue on its present course and eventually collapse naturally. Additional ponderosa pine and possibly southwestern white pine mortality would occur. Stand structure, density, and species composition would continue to change resulting in more openings, and a shift in species composition towards more hardwoods and white fir and Douglas-fir. Stand density would be reduced further, particularly in areas where ponderosa pine is now prevalent. Additional snags and eventually down woody material would be created. Effects to wildlife species would depend on the species and their food and habitat preferences. Fuel loading would increase. Areas where mortality would be most likely to occur would be those where ponderosa pine is abundant and where stand conditions are dense and with a substantial number of trees larger than 6 inches DBH.

2. **Salvage**. Both currently infested and dead trees would be removed via harvesting prior to beetle emergence in the next season. Goal is to utilize timber resource, remove potential hazard trees, and suppress beetle population.

Where Applicable. Salvage operations are most effective in reducing beetle-caused mortality when initiated while beetle populations are still increasing. They may be useful in areas where additional mortality would be detrimental to accomplishment of short-term management objectives. A quick implementation time is required. Appropriate areas may include those accessible to logging or fuelwood operations, such as, near existing roads and on less than 40% slopes as well as those where dead trees may in the long run pose a risk to people or property. Salvage operations are appropriate for areas where harvesting activity does not pose a threat to special resource values, including sensitive or threatened species.

Effects. When implemented and completed prior to beetle emergence and applied to the entire outbreak area, salvage logging has reduced beetle-caused tree mortality. However, this alternative does not change the underlying stand conditions that contribute to the outbreak. Therefore, once conditions are again favorable for an outbreak, i.e. a drought occurs, another outbreak can occur. Fuel loading would be decreased. Timber resource would be utilized. Future snags would be removed. Adverse site disturbance could occur.

3. **Mechanical Control.** Fell and buck infested trees and treat them by either burning, peeling and burning the bark, chipping, applying toxic sprays, or piling and covering with clear plastic. Treatments must be completed prior to beetle emergence. Goal is to suppress beetle population.

   Where applicable. This method may be useful in areas where logging is impractical, such as on steep slopes, or sensitive areas where ground disturbance from logging equipment would cause adverse impacts and where additional tree mortality threatens accomplishment of short term management objectives. As with (2) a quick implementation schedule is required.

   Effects. Main effects are the same as for (2), however, less physical disturbance to the site results. Use of toxic sprays can adversely affect other organisms in the environment and would require preparation of an Environmental Impact Statement. Mechanical control alone does not change underlying stand conditions and can also be expensive, particularly since some of the methods are very labor intensive and no timber volume is recovered. Fuel loading would be increased. Future snags would be removed.

4. **Sanitation/Salvage.** This alternative combines removal of dead and infested trees and susceptible uninfested trees. Goal is to suppress beetle population, utilize timber resource, and reduce long-term stand susceptibility to beetle attack.

   Where applicable. This alternative may be useful in areas accessible and appropriate for logging and where future beetle-caused mortality would adversely affect desired future condition. If completed in a timely manner, it may prevent beetle-caused mortality in stands adjacent to or nearby those currently infested. A short implementation schedule is required.

Effects. Use of this alternative can reduce amounts of tree mortality both in the short-term and long-term. It allows the manager to determine what stand conditions he or she would like to manage for in the future. On the other hand, it removes dead trees which would otherwise develop into snags and may cause adverse site disturbance.

5. **Modified Sanitation Salvage**. Remove infested trees and susceptible uninfested trees. The goal is to suppress the population and reduce stand susceptibility while leaving dead uninfested trees to develop into snags and down woody material.

   Where Applicable. This method would be applicable for the same areas as option 4, but in addition where there is concern about loss of snags for wildlife habitat.

   Effects. Same as (4), but would leave a number of dead trees for future snags.

6. **Protection of high value trees using insecticides**. Prior to beetle flight, boles of valuable trees can be sprayed with carbaryl to prevent bark beetle attack.

   Where Applicable. This method might be applicable in campgrounds, around homes, or administrative sites. Insecticide application is not effective for trees that have already been attacked.

   Effects. Spraying trees will prevent successful attack for up to 2 years. This pesticide is toxic to all insects and could cause mortality to a variety of non-target insects. It has a low mammalian toxicity, and low residual activity (remains in the environment for a short time). Treatment would not affect beetle population and can also be expensive.

TECHNICAL INFORMATION

Roundheaded Pine Beetle

The roundheaded pine beetle, Dendroctonus adjunctus Blandford, occurs throughout the southwest and may be found on ponderosa pine, white pines, and Chihuahua pine. It is often mistaken for other species, such as the mountain pine beetle, which it resembles. This beetle produces one generation per year. The main attack period is during October and November. Foliage usually fades the following year in May or June (Chansler 1967). A portion of the population attacks in May or early June, usually several weeks after western pine beetle or mountain pine beetle (Wood 1982).

External evidence consists first of pitch tubes and later fading foliage. Underneath the bark, egg galleries wind longitudinally with the grain and average 31 centimeters in length (Wood 1982). Galleries are numerous and often cross (Chansler 1967). As with other Dendroctonus spp. egg galleries are packed with frass. Larval galleries wander generally at right angles to the

parent galleries. Larvae first feed in the inner bark but complete development in the dry outer bark (Chansler 1967).

In the Southwest, this insect usually attacks and kills weakened ponderosa pines. The average diameter of attacked pines from past outbreaks in New Mexico has varied from 9 inches in the 1960s to to 6.5 inches in a 1970s outbreak (Chansler 1967, Stevens et. al. 1974). Stevens et. al. (1974) reported that mortality was concentrated in the codominant trees. Meanwhile, outbreaks in southern Nevada have been primarily restricted to larger size classes (Massey et al 1977).

Outbreaks have been reported from southern New Mexico and Nevada. In New Mexico outbreaks have occurred approximately at 10 year intervals since the 1950s (Massey et al 1977). The largest one occurred in the 1970s, covering 400,000 acres. A current outbreak has killed approximately 100,000 trees over 87,000 acres since 1990. Trees are generally attacked in groups of 3 to 15, although some groups may have more than 100 trees (Chansler 1967). The 1970s outbreak resulted in reductions of up to 50 percent in TPA and BA. The main effect was a thinning, and in mixed species stands a shift in species composition favoring non host species (Stevens et. al. 1974).

No management guidelines are described for this insect, however, we suspect that preventive measures described for other Dendroctonus spp. would be appropriate. Thus, treatments that reduce competition and disease levels should reduce susceptibility.

Western Pine Beetle

The western pine beetle, Dendroctonus brevicomis LeConte, attacks ponderosa pine in the Southwest. Between two and four generations are produced per year depending on latitude and elevation (Demars 1982). Flight and attacks start in late spring or early summer and continue until the onset of cold weather. Attacks are initiated by adult females, usually at mid bole. Evidence of attack is marked by white to reddish pitch tubes on the bark. The attack process is mediated by chemical messengers or pheromones released by the beetles in combination with host terpenes. Winding sinuous egg galleries are constructed under the bark by adults. These galleries often cross. These egg galleries are packed with boring dust. Eggs are laid in niches chewed into the sides of the gallery. Larvae hatch and feed in short galleries perpendicular to the parent gallery. Later larval stages feed in the middle bark where pupation also occurs. Brood adults first feed in the middle and outer bark before emerging. The cycle varies in length from two to ten months depending on temperature.

This insect usually breeds in scattered, slow growing overmature trees and diseased or damaged trees (Demars et. al. 1982). Group killing is also common in densely stocked stands of young sawtimber. However, trees under 6 inches in diameter are seldom attacked. Environmental stresses which permanently weaken individual or small groups of trees (root diseases, mistletoes, mechanical damage) or temporarily weaken whole stands (droughts, defoliators, fires) predispose trees to attack and create conditions for outbreaks to occur.

There are a number of natural enemies of this insect including woodpeckers, and several parasitic and predatory insects (Otvos 1970, Dahlsten 1970). Extremely cold winter temperatures can also result in significant brood mortality (Demars et. al. 1982). However, the main factor thought to influence occurrence of outbreaks is the abundance of suitable hosts (Demars et. al. 1982).

The direct effect of western pine beetle attack is tree mortality. As with other bark beetles, the effects of this can be positive or negative depending on the degree of mortality and the resource values involved. Effects of bark beetles on timber resources are generally negative. On the other hand, scattered and even clumps of mortality can be beneficial to wildlife by creating snags, down woody material, and openings. Bark beetles are also a food source for some species of wildlife, particularly woodpeckers. However, extensive mortality could reduce hiding and thermal cover in affected areas. Dead trees with red foliage can be unsightly to people recreating, however, once the trees turn grey they are apparently less noticeable.

Where tree mortality is a concern, prevention of outbreaks is the most effective way of reducing losses. Unacceptable losses can be prevented in most circumstances (barring severe drought) by maintaining thrifty, vigorous trees. Thinning dense 70-80 year old sawtimber stands, reducing stocking to less than 70 percent of the basal area necessary for full site utilization, relieves competitive stress among remaining trees, making them less susceptible to attack (Demars et. al. 1982).

Pine Engravers

Several species of pine engraver beetles, Ips spp., attack downed and standing ponderosa pine in the southwest. The beetles usually produce 2-4 generations per year depending on climate and elevation (Parker 1979, Sartwell et al 1971). Flight and attacks usually begin in April or May, whenever daily maximum temperatures reach 60-70 degrees F. (Livingston 1979) and continue until the onset of cold weather. Engraver beetle attacks are initiated by adult males. The attack process is mediated by pheromones released by the beetles in combination with host terpenes. The male is joined by one to many females. After mating each female constructs an egg gallery in the inner bark, slightly scoring the wood surface. Egg galleries are not packed with boring dust, this distinguishes them from the Dendroctonus spp., such as the western pine beetle. Eggs are laid on each side of the gallery. Larvae feed in mines that run laterally from the egg gallery. The larval mines are packed with frass. Pupation occurs in an oval cell chewed by the larva. In the southwest this cycle varies in length from about one month in mid summer to eighty days at other times (Parker 1979).

External evidence of attack consists of accumulations of reddish brown boring dust in bark crevices and at the base of the tree, small entrance holes, and occasionally pitch tubes on living trees. When the bark is removed from infested trees, the galleries can be seen in the inner bark or on the surface of the sapwood.

These insects prefer to attack freshly cut slash, windthrow, and snow broken material (Livingston 1979). Standing green trees may also be attacked, but often only the tops are killed on large trees. The minimum diameter of attack is around 4 inches. A number of factors may increase the risk of pine engraver mortality including:

1. Presence of green slash or snow broken material in spring (January - June) (Livingston 1979, Parker 1979),

2. Spring drought (less than 75 percent of normal precipitation) (Livingston 1979),

3. Stagnated stand conditions, particularly high density pole-sized stands (Livingston 1979),

4. Diseases such as dwarf mistletoe (Parker 1979).

Over 80 percent of outbreaks are primarily associated with slash or weakened trees created during forest management operations (Parker 1979). The most extensive outbreaks occur when fresh slash or weakened trees are present in the same area for two or more consecutive years.

The effects of engraver beetle attack include tree mortality and top-kill. Trees that have been top-killed are often attacked by Dendroctonus spp., such as the western pine beetle, roundheaded pine beetle, or red turpentine beetle, in the lower bole within the same year or subsequent years. Overall effects of mortality are the same as with other bark beetles.

Preventive measures are most effective in reducing losses. The following tactics are recommended for this purpose. Many of these are described in the Cutting Methods Handbook (2409.26a, Chapter 62).

1. Where the threat of Ips-caused mortality is a concern, slash creating activities should be conducted from July-December. Minimize creation of slash during the months of January-June.

2. When it is impractical to do this, slash should be treated so as to make it less suitable for the beetles. This may include chipping or crushing. The handbook also mentions burning, however, it has been our experience that burning is not accomplished until many months after the slash is created, by which time the beetles have already emerged, so this method may not be practical. Exposing as much of the slash to the sun as possible will reduce brood production. In some situations, a lop and scatter treatment to promote drying may be sufficient. Brood production has been shown to be greatest in piled slash and unlopped tops in California.

3. Avoid management activities that create slash or weakened trees for two or more consecutive years in the same area or adjacent areas. We recommend separating activities by 2 miles or more.

4. Maintain or improve stand vigor through precommercial and commercial thinning.

5. Utilize harvested material to a 4 inch top (diameter outside bark). Few beetles are produced in debris below 4 inches in diameter because of the limited amount of food reserve in the inner bark.

6. Monitor green slash and standing trees for evidence of infestation, particularly during April - July in drought years, should large numbers of Ips be detected, a pest management specialist can be consulted.

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TABLE 1

TREES PER ACRE (TPA) AND BASAL AREA PER ACRE (BA) BY SIZE CLASS AND SPECIES FOR ZONE 1.

	SIZE CLASS							
	SEEDLINGS		SAPLINGS		OVERSTORY			
SPP	TPA	%	TPA	%	TPA	%	BA	%
ASPEN	72.7	13.3	0	0	20.7	6.8	9.6	3.9
GAMBEL OAK	0	0	27.3	5.4	0	0	0	0.0
WHITE FIR	45.5	8.3	54.6	11.0	22.3	7.4	19.1	7.7
DOUGLAS FIR	345.7	63.4	354.7	70.9	69.4	23.0	82.7	33.3
PONDEROSA PINE	0	0	36.4	7.3	69.9	23.2	63.6	25.6
SW WHITE PINE	81.9	15.0	27.3	5.4	119.6	39.6	73.2	29.5
TOTAL	545.8	100.0	500.3	100.0	301.9	100.0	248.2	100.0

TABLE 2

OVERSTORY TREES PER ACRE (TPA) AND BASAL AREA PER ACRE (BA) BY TREE CONDITION FOR ALL SPECIES FOR ZONE 1

	LIVE	INFESTED	DEAD	TOTAL
TPA	274.1	10.7	17.1	301.9
PERCENT	90.8	3.5	5.7	100.0
BA	222.8	19.1	6.4	248.2
PERCENT	89.8	7.6	2.6	100.0

TABLE 3

PONDEROSA PINE TREES PER ACRE BY DIAMETER CLASS (DBH) AND TREE CONDITION FOR ZONE 1

DBH	HEALTHY	TOTAL INFESTED[a]	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	STAND TOTAL
0	0	0	0	0	0	0
1	9.1	0	0	0	0	9.1
2	0	0	0	0	0	0
3	9.1	0	0	18.2	18.2	27.3
4	0	0	0	0	0	0
6	16.2	0	0	16.2	16.2	32.4
8	9.1	0	0	0	0	9.1
10	0	0	0	0	0	0
12	0	0	0	0	0	0
14	3.0	3.0	3.0	0	0	6.0
16	6.9	2.3	2.3	0	0	9.2
18	1.8	3.6	1.8	0	0	5.4
20	0	0	0	0	0	0
22	0	3.6	3.6	0	0	3.6
24	0	0	0	0	0	0
26	2.7	0	0	0.9	0.9	3.6
28	0	0	0	0	0	0
30	0	0	0	0	0	0
32	0.6	0	0	0	0	0.6
TOTAL	58.5	12.5	10.7	35.3	35.3	106.3
%	55.1	11.7	10.1	33.2	33.2	100.0

[a] All pest species

TABLE 4

PONDEROSA PINE BASAL AREA PER ACRE BY DIAMETER CLASS (DBH) AND TREE CONDITION FOR ZONE 1

DBH	HEALTHY	TOTAL INFESTED	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	STAND TOTAL
6	3.2			3.2	3.2	6.4
8	3.2					3.2
10						0
12						0
14	3.2	3.2	3.2			6.4
16	9.5	3.2	3.2			12.7
18	3.2	6.4	3.2			9.5
20						0
22		9.5	9.5			9.5
24						0
26	9.5			3.2	3.2	12.7
28						0
30						0
32	3.2					3.2
TOTAL	35.0	22.3	19.1	6.4	6.4	63.6
PERCENT	55.0	35.0	30.0	10.0	10.0	100.0

TABLE 5

TREES PER ACRE (TPA) AND BASAL AREA PER ACRE (BA)
BY SIZE CLASS AND SPECIES FOR ZONE 2

	SIZE CLASS							
	SEEDLINGS		SAPLINGS		OVERSTORY			
SPP	TPA	%	TPA	%	TPA	%	BA	%
ASPEN	66.6	19.0	8.3	10.0	35.8	12.5	14.6	7.2
WHITE FIR	91.6	26.2	8.3	10.0	27.2	9.5	23.3	11.4
DOUGLAS FIR	50.0	14.3	8.3	10.0	15.6	5.4	35.0	17.1
PONDEROSA	50.0	14.3	0.0	0.0	49.8	17.4	67.1	21.4
SW WHITE PINE	91.6	26.2	58.3	70.0	158.2	55.2	87.5	42.9
TOTAL	349.8	100.0	83.2	100.0	286.6	100.0	204.2	100.0

TABLE 6

OVERSTORY TREES PER ACRE (TPA) AND BASAL AREA PER ACRE (BA)
BY TREE CONDITION FOR ALL SPECIES FOR ZONE 2

	HEALTHY	INFESTED	DEAD	TOTAL
TPA	258.3	16.2	12.1	286.6
PERCENT	90.3	5.5	4.2	100.0
BA	183.8	5.8	14.6	204.2
PERCENT	87.1	5.7	7.1	100.0

TABLE 7

PONDEROSA PINE TREES PER ACRE BY DIAMETER CLASS ZONE 2
(DBH) AND TREE CONDITION FOR ZONE 2

DBH	HEALTHY	TOTAL INFESTED	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	TOTAL
6	14.9	14.9	14.9			29.8
8						0.0
10						0.0
12				7.4	7.4	7.4
14						0.0
16				2.1	2.1	2.1
08				1.7	1.7	1.7
20	3.9	1.3	1.3			5.2
22						0.0
24		0.9		0.9	0.9	1.8
26						0.0
28		0.7				0.7
30	0.6					0.6
32	0.5					0.5
TOTAL	19.9	17.8	16.2	12.1	12.1	49.8
PERCENT	40.0	35.7	32.5	24.3	24.3	100.0

TABLE 8

PONDEROSA PINE BASAL AREA PER ACRE BY DIAMETER CLASS
(DBH) & TREE CONDITION FOR ZONE 2

DBH	HEALTHY	TOTAL INFESTED	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	STAND TOTAL
6	2.9	2.9	2.9			5.8
8						0.0
10						0.0
12				5.8	5.8	5.8
14						0.0
16				2.9	2.9	2.9
18				2.9	2.9	2.9
20	8.8	2.9	2.9			11.7
22						0.0
24		2.9		2.9	2.9	5.8
26						0.0
28		2.9				2.9
30	2.9					2.9
32	2.9					2.9
TOTAL	17.5	11.7	5.8	14.6	14.6	43.8
PERCENT	40.0	26.7	13.2	33.3	33.3	100.0

TABLE 9

TREES PER ACRE (TPA) AND BASAL AREA PER ACRE (BA)
BY SIZE CLASS AND SPECIES FOR ZONE 3

SPP	SEEDLINGS		SAPLINGS		OVERSTORY			
	TPA	%	TPA	%	TPA	%	BA	%
ASPEN	0.0	0.0	9.1	7.7	51.5	15.5	19.1	15.5
WHITE FIR	63.6	22.6	18.2	15.4	9.6	4.5	9.5	2.9
DOUGLAS FIR	63.7	22.6	18.2	15.4	46.7	12.1	25.5	14.0
PONDEROSA PINE	9.1	3.2	18.2	15.4	162.9	56.1	117.7	48.9
SW WHITE PINE	145.5	51.6	54.6	46.1	62.3	18.2	38.2	18.7
TOTAL	281.9	100.0	118.3	100.0	333.3	100.0	210.0	100.0

TABLE 10

OVERSTORY TREES PER ACRE (TPA) AND BASAL AREA PER ACRE (BA)
BY TREE CONDITION FOR ALL SPP FOR ZONE 3

	HEALTHY	INFESTED	DEAD	TOTAL
TPA	219.0	96.9	17.4	333.3
PERCENT	65.7	29.1	5.2	100.0
BA	124.1	73.2	12.7	210.0
PERCENT	59.1	34.8	6.1	100.0

TABLE 11

PONDEROSA PINE TREES PER ACRE BY DIAMETER CLASS (DBH) AND TREE CONDITION FOR ZONE 3

DBH	HEALTHY	TOTAL INFESTED	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	STAND TOTAL
0	9.1					9.1
1						0.0
2						0.0
3						0.0
4	9.1	9.1	9.1			18.2
6		16.2	16.2			16.2
8	36.4	18.2	18.2	9.1	9.1	63.7
10	5.8	29.0	23.2			34.8
12	8.2	4.1	4.1	4.1	4.1	16.4
14	6.0	6.0	6.0	3.0	3.0	15.0
16		2.3	2.3			2.3
18		3.6	3.6			3.6
20	3.0	1.5	1.5			4.5
22				1.2	1.2	1.2
24						0.0
26	0.9	1.8	1.8			2.7
28	0.7	0.7	0.7			1.4
30		0.6	0.6			0.6
32						0.0
34	0.5					0.5
TOTAL	79.7	93.1	87.3	17.4	17.4	190.2
PERCENT	41.9	48.9	46.0	9.1	9.1	100.0

TABLE 12

PONDEROSA PINE BASAL AREA PER ACRE BY DIAMETER CLASS (DBH) & TREE CONDITION FOR ZONE 3

DBH	HEALTHY	TOTAL INFESTED	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	STAND TOTAL
6		3.2	3.2			3.2
8	12.7	6.4	6.4	3.2	3.2	22.3
10	3.2	15.9	12.7			19.1
12	6.4	3.2	3.2	3.2	3.2	12.7
14	6.4	6.4	6.4	3.2	3.2	15.9
16		3.2	3.2			3.2
18		6.4	6.4			6.4
20	6.4	3.2	3.2			9.5
22				3.2	3.2	3.2
24						0.0
26	3.2	6.4	6.4			9.5
28	3.2	3.2	3.2			6.4
30		3.2	3.2			3.2
32						0.0
34	3.2					3.2
TOTAL	44.5	60.5	57.3	12.7	12.7	117.7
PERCENT	37.8	51.4	48.7	10.8	10.8	100.0

TABLE 13

WHITE PINE TREES PER ACRE BY DIAMETER CLASS (DBH) AND TREE CONDITION FOR ZONE 3

DBH	HEALTHY	TOTAL INFESTED	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	STAND TOTAL
6	16.2					16.2
8	9.1					9.1
10	5.8	5.8	5.8			11.6
12	12.3					12.3
14	6.0	3.0				9.0
16		2.3	2.3			2.3
18		1.8	1.8			1.8
TOTAL	49.4	12.9	9.9	0	0	62.3
PERCENT	79.3	20.7	15.9	0	0	100.0

TABLE 14

WHITE PINE BASAL AREA PER ACRE BY DIAMETER CLASS
(DBH) AND TREE CONDITION FOR ZONE 3

DBH	HEALTHY	TOTAL INFESTED	BEETLE INFESTED	TOTAL DEAD	BEETLE DEAD	STAND TOTAL
6	3.2					3.2
8	3.2					3.2
10	3.2	3.2	3.2			6.4
12	9.5					9.5
14	6.4	3.2				9.5
16		3.2	3.2			3.2
18		3.2	3.2			3.2
TOTAL	25.5	12.7	9.5	0	0	38.2
PERCENT	66.7	33.3	24.9	0	0	100.0

Figure 1
1988 Ponderosa Pine Mortality

• 1-10 Trees ○ >10 Trees

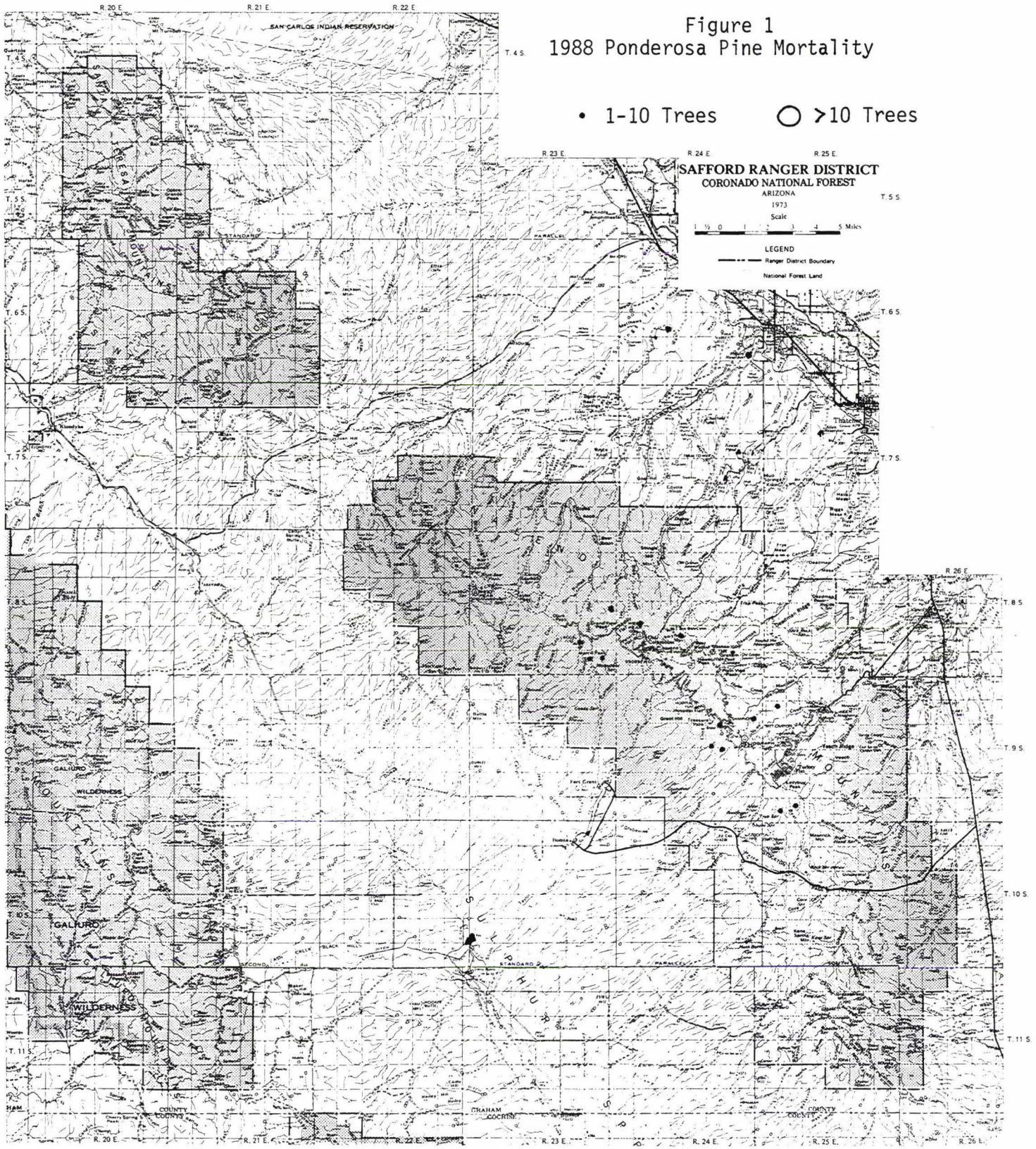


Figure 2
1989 Ponderosa Pine Mortality

• 1-10 Trees ○ >10 Trees

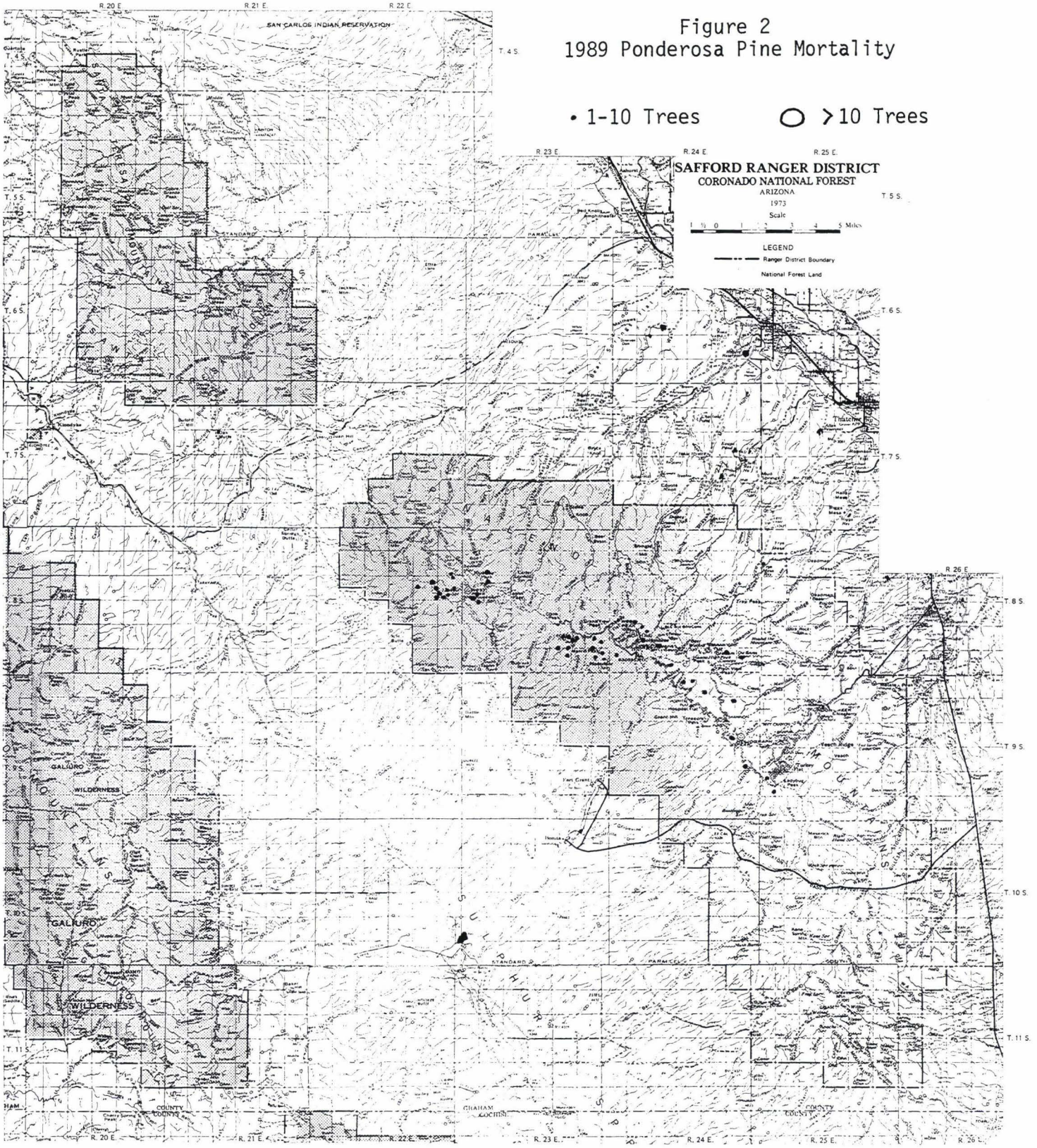


Figure 3
1990 Ponderosa Pine Mortality

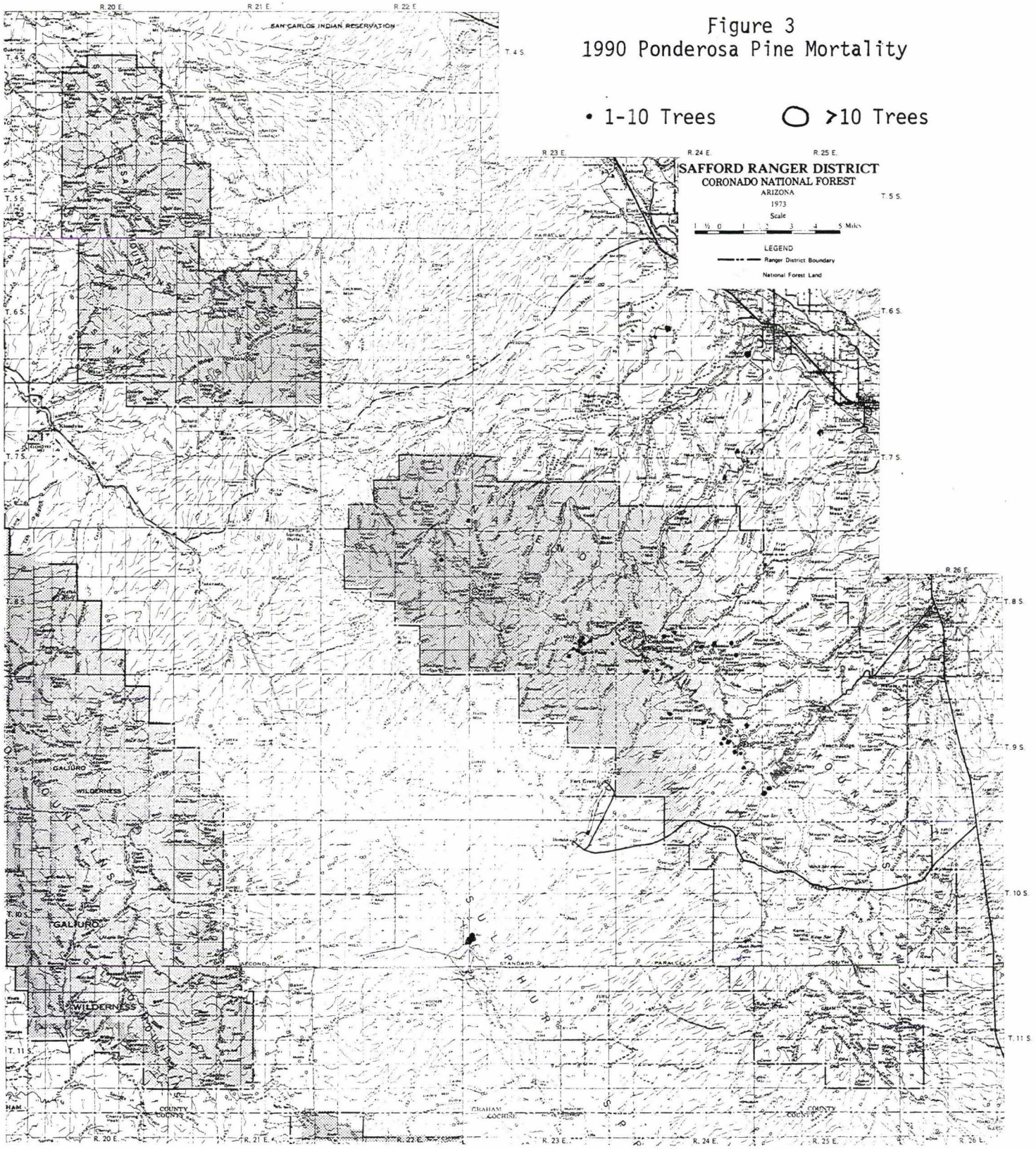
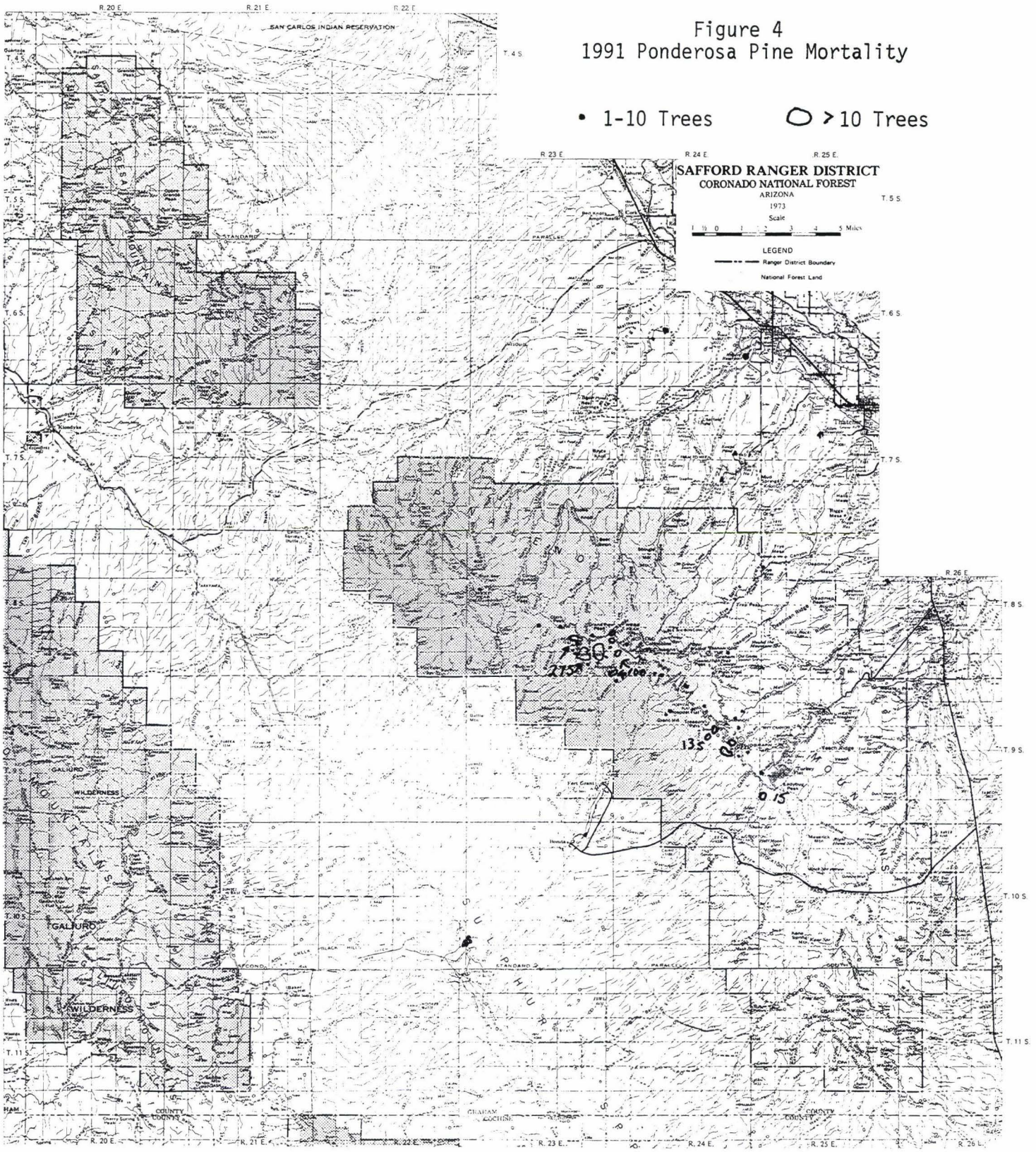


Figure 4
1991 Ponderosa Pine Mortality



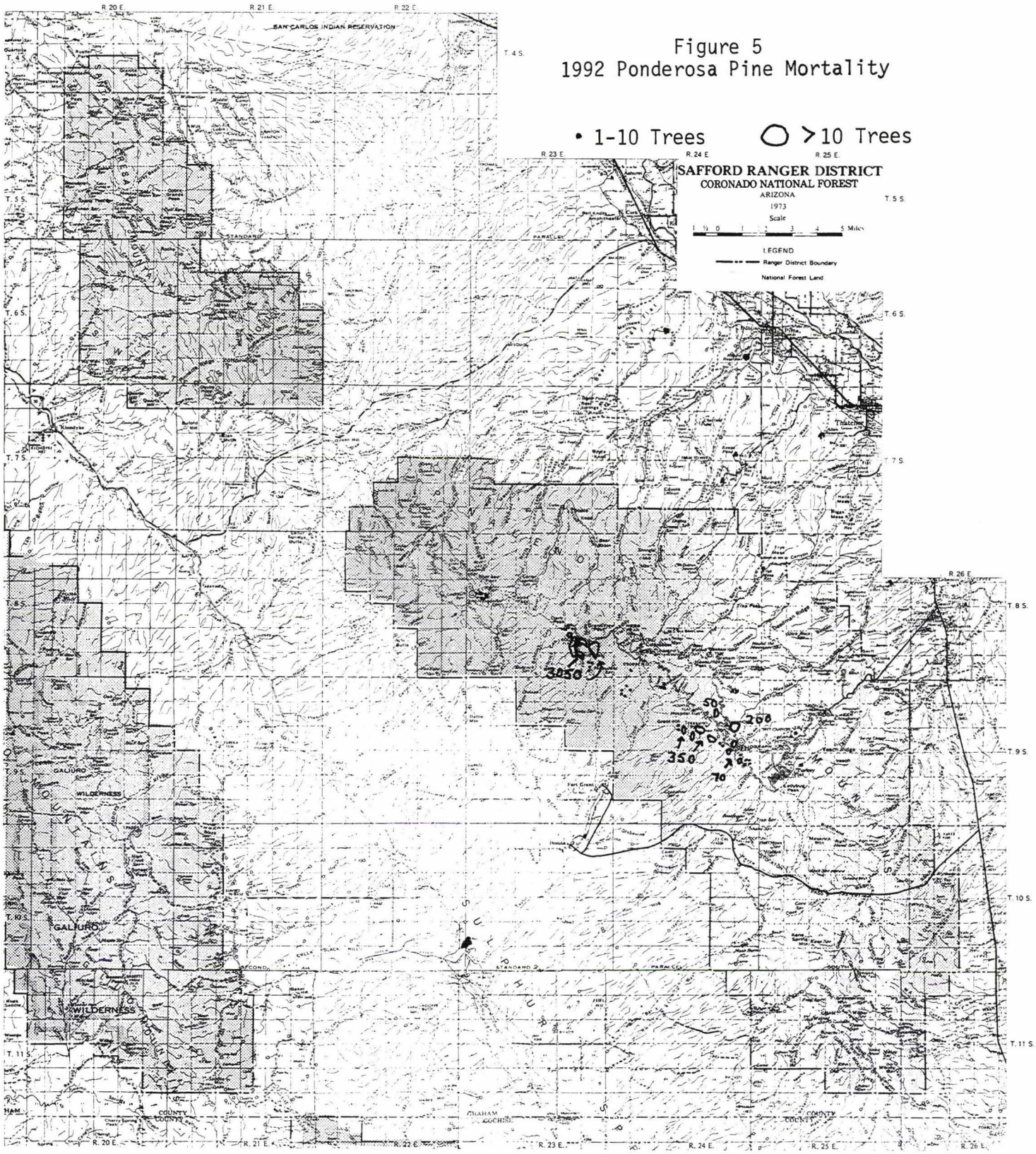


Figure 5
1992 Ponderosa Pine Mortality
• 1-10 Trees
>10 Trees
SAFFORD RANGER DISTRICT
CORONADO NATIONAL FOREST
ARIZONA
1973
Scale
LEGEND
Ranger District Boundary
National Forest Land
SAN CARLOS INDIAN RESERVATION
GALIURO WILDERNESS
GALIURO
WILDERNESS
3050
350
70
200
R. 20 E.
R. 21 E.
R. 22 E.
R. 23 E.
R. 24 E.
R. 25 E.
R. 26 E.
T. 4 S.
T. 5 S.
T. 6 S.
T. 7 S.
T. 8 S.
T. 9 S.
T. 10 S.
T. 11 S.

FIGURE 6

Ground Survey Zones
and Transect Lines
for Riggs Flat Survey